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Technology Transfer of Biopolymer Soil Amendment for Rapid Revegetation and Erosion Control at Fort A. P. Hill, Virginia

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PURPOSE: Sustainable land management at Army installations is a critical concern of the modern Army and the Army engineer. A unique soil additive consisting of a polysaccharide polymeric material, a natural product of plant/soil rhyzobial microbial activity, was demonstrated to enhance site vegetation and control erosion. The effort was supported by the Environmental Security Technology Certification Program (ESTCP, Project ER-0920) of the Department of Defense. *Rhizobium tropici*, a catalogued symbiotic nodulator of leguminous plants (Martinez-Romero et al. 1991), is also known for its prolific production of a gel-like, extracellular polymeric substance (EPS), a biopolymer (Gil-Serrano et al. 1990). The natural functions of the EPS in the rhizosphere include surface adhesion, self-adhesion of cells into biofilms, formation of protective barriers, water retention around roots, and nutrient accumulation (Laspidou and Rittmann 2002). The secretion of EPS by bacteria is recognized as a cohesive force in promoting surface erosion resistance in sediments (Droppo 2009, Gerbersdorf et al. 2008a, 2008b).

This biopolymeric material is produced commercially in dedicated bioreactors, separated from the growth media and derivatized in order to produce a non-reactive (non-crosslinking) material (Newman et al. 2010, Patent No. 7,824,569). Addition of *R. tropici* biopolymer to disturbed soil along with normal grass seeding activities has, through laboratory and field demonstrations, been shown to be an effective and low-cost method of reducing soil erosion and facility maintenance costs (Larson et al. 2012, Muller and Farr 2015). The biopolymer is non-toxic and — while long-lived — is ultimately biodegradable (MSDS). The case study described in this Technical Note (TN) evaluates application of this biopolymer to a highly disturbed and erodible soil.

BACKGROUND: Most training areas present soil erosion challenges from the production of dust and from reduced vegetation growth that results from heavy use (Figure 1). Maintenance of these areas is important for enhancing training land usage and availability.

At Fort A.P. Hill, any land disturbance greater than 2,500 ft^2 requires both an Erosion & Sediment (E&S) Control Plan and a Stormwater Pollution Prevention Plan (SWPPP). The field demonstration site, an airplane landing zone, is an area that has required extensive repair and maintenance over many years and has failed to meet the requirements outlined in the E&S Control Plan and the SWPPP.

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Figure 1. Examples of the maintenance challenges posed by training on military installations.

OBJECTIVE: The objective of the Fort A.P. Hill field study was to demonstrate the effectiveness and ease of biopolymer application. The biopolymer application can be completed using maintenance equipment normally found on Armed Forces installations and as part of routine installation maintenance in order to meet installation soil erosion control requirements.

SOIL CHARACTERIZATION: Bulk site soil samples were extracted and analyzed for metals using USEPA SW846 Method 3050. Metals analysis was performed by inductively coupled plasma mass spectrometry (ICP-MS). Soil pH was determined by electrode. The soil is characterized as a Sandy Loam. The metals analysis is shown in Table 1. Only one metal, aluminum (Al), shaded red, was present at a concentration well above the national average and above the range of concentration found across the conterminous United States (Shacklette and Boergen 1984). Aluminum is known to be toxic to plants at this concentration (Kochian 1995, Ma and Hiradate 2000, Ma et al. 2001; Ryan and Kochian 1993, and others). Soil pH was 4.73.

Table 1. Concentrations (mg/Kg) of select metals in the soil of the Fort A.P. Hill demonstration site as compared to national averages.

Metal	Fort A.P. Hill (avg/stdev, mg/Kg)	U.S. avg* (mg/Kg)	U.S. range* (mg/Kg)
Aluminum (Al)	340,600/3,470	72,000	700 - >10,000
Sodium (Na)	37,127/2,920	12,000	<500 - 100,000
Cobalt (Co)	1.6/0.1	91	<3 – 70
Magnesium (Mg)	264/3	9,000	50 - >100,000
Calcium (Ca)	135/24	24,000	100 – 320,000
Chromium (Cr)	10.2/0.2	54	1 – 2,000
Manganese (Mn)	12/0.3	550	<2 – 7,000
Iron (Fe)	10,589/223	26,000	100 - >100,000
Nickel (Ni)	3/0.2	19	<5 – 700
Copper (Cu)	14/2	25	<1 – 700
Zinc (Zn)	21/6	60	<5 – 2,900
Lead (Pb)	5/1	19	<10 – 700

*Shacklette and Boergen (1984)

FIELD DEMONSTRATION: The purpose of the field demonstration at Fort A.P. Hill was three-fold:

- To control soil erosion from runoff water on the site
- To increase the germination rate and density of the vegetation (native grasses)
- To provide technology transfer to the Fort A.P. Hill DPW personnel with hands-on training in the application of the biopolymer.

The field demonstration site was a 3.8-acre area off Mosbey Rd. near the Airfield Landing area. This site, constructed in 2003, had never been seeded and little volunteer vegetation had been established. The site was divided into Area 1 and Area 2 (Figure 2); both consisted of a mostly sandy loam soil with 3-4-foot-deep ruts, small woody vegetation, some weeds, and little to no grass (Figure 3). The areas are adjacent to West Branch Mount Creek, which receives the runoff water.

Figure 2. Aerial view of the Fort A.P. Hill field demonstration.

Figure 3. Area 1 prior to site preparation.

The biopolymer, produced by NanoQuantics, Inc. (Wise, VA), a subsidiary of UXB International, was applied to both areas along with a custom grass seeding mix (700 lb). The seed mix was composed of

- Gulf annual ryegrass - 38.4%;
- VNS perennial ryegrass - 28.8%;
- Boreal red fescue - 29.51%; and
- other inert material - 3.29%.

The demonstration was begun on 26 May 2015. The Fort A.P. Hill Department of Public Works (DPW) determined that Area 1 and Area 2 required reconstruction prior to seeding. The site was prepared using construction equipment and trained operators available on the installation: bulldozers, a road grader, scraper, and tractors (Figure 4).

Figure 4. Earthwork using a bulldozer and road grader available, with trained operators, on-site.

Standard Operation and Maintenance (O&M) of grassed areas at Fort A.P. Hill requires soil fertilization and liming prior to seeding. After reconstruction of the site, biopolymer, fertilizer, lime, and grass seed were also applied to the soil. These activities also used equipment and trained operators available on the installation: a hydroseeder, a drill seeder, and a 3-point broadcast spreader.

1. The site was first disked with a tractor (Figure 5).
2. A tractor with a 3-point broadcast spreader spread 133, 40-pound bags (2.7 tons) of pellet lime over Areas 1 and 2 (Figure 5).
3. Next, 66 40-pound bags (1.3 ton) of 10-10-10 fertilizer was spread over Area 1 and 13, 50-pound bags (0.3 ton) of 20-0-20 fertilizer was spread over Area 2.

   Note: These operations may not be required on all installations.

Figure 5. Disking the soil and broadcast application of lime and fertilizer using equipment and trained operators available on-site.

A cultipacker was used to place the seeds in the soil. A broadcast spreader also works well. The biopolymer was prepared by adding 500 gallons of water and 25 gallons of biopolymer — a 20:1 dilution ratio — in the hydroseeder, which homogenized the biopolymer solution (Figure 6).

Alternatively, the hydroseeder can be used to place seed and biopolymer at the same time.

Figure 6. Application of biopolymer and the seed mixture using a hydroseeder and broadcast spreader. Equipment and trained operators were available on-site.

At Fort A.P. Hill, hay bales were placed around the site perimeter to control potential erosion from heavy rains until grass was established (Figure 7).

This step is also optional if stormwater runoff is not a consideration.

Figure 7. Cultipacking and finishing the field using equipment and trained operators available on-site.

The results of the revegetation effort at Fort A.P. Hill are presented in Figure 8 and show successful germination and rapid increase in biomass. The effort to reduce soil erosion was proven successful within one week postplanting. During the first five days of June, immediately following completion of the seeding effort, Fort A.P. Hill received 2.9 in. of rainfall. Over 1.3 in. of this fell in one day (see Figure 8, left). The total rainfall for June was only 5.99 in. (National Climatic Data Center (NCDC), http://www.ncdc.noaa.gov accessed 9 September 2015). DPW personnel reported minimal erosion damage from the early rain events.[1]

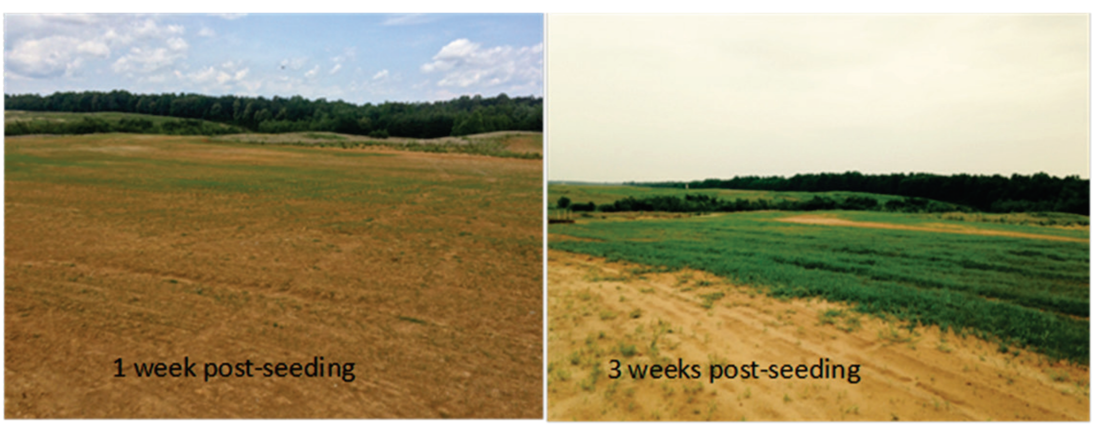

Figure 8. Rapid seed germination evident at seven days and significant biomass production at three weeks post-planting.

[1] Personal communication. 2015. John Parker, Environmental & Natural Resources Division, Fort A.P. Hill.

There is evidence from the metals analysis that establishment of vegetation on the site is slowed due to the acid pH of the soil combined with high concentrations of aluminum. Liming efforts promoted in the standard O&M guidelines of Fort A.P. Hill provide some protection for germinating seeds. However, aluminum is known to reduce the size of the taproot and the root branching topology (Delhaize and Ryan 1995, Ma et al. 2001, Serrano et al. 2011). When the pH increase produced from the lime has been expended, there is a decrease in plant biomass and eventual plant death. When the grass has died, the soil is no longer resistant to erosion by runoff water and wind. Evidence presented by Flis et al. (1993) suggests that the presence of cell surface components such as exopolysaccharides in the rhizosphere, like the *R. tropici* biopolymer, can lower the aluminum toxicity sufficiently to allow plant growth. The biopolymer soil amendment also promotes soil particle aggregation. This increases the resistance of the soil to erosion from surface water runoff (Larson et al. 2012).

SUMMARY AND CONCLUSIONS: The field demonstration at Fort A. P. Hill had the following objectives:

- To establish desired vegetation at a site previously unseeded
- To control soil erosion in an erodible soil on a disturbed site
- To demonstrate the ease of applying the biopolymer using maintenance equipment normally found on Armed Forces installations and as part of routine installation maintenance
- To improve vegetative growth on the site when biopolymer was used in conjunction with standard O&M procedures

These objectives were all successfully accomplished.

The protection of plants from aluminum toxicity in acid soils using exopolysaccharides should be further investigated.

ADDITIONAL INFORMATION: This TN was prepared by Dr. Steve Larson, Dr. W. Andy Martin, Roy Wade, and Richard Hudson of the Environmental Engineering Branch, Environmental Laboratory, U.S. Army Engineer Research and Development Center, and Catherine Nestler of Applied Research Associates, Inc. (ARA), Vicksburg, MS. Funding was provided by Headquarters Department of the Army (HQDA), Office of the Assistant Chief of Staff for Installation Management (OACSIM). The demonstration was supported by the Department of Public Works at Fort A.P. Hill, VA. For additional information, contact Dr. Steve Larson (601) 634-3431, steve.l.larson@erdc.dren.mil or Dr. Andy Martin (601) 634-3710 andy.martin@usace.army.mil.

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